

## Lecture Module - Introduction

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

### Topic 1 - Introduction

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- Topic 1 - General Measurement System
- Topic 2 - Types of Variables
- Topic 3 - Experimental Test Plan
- Topic 4 - Numbers and Storage

## Topic 1 - General Measurement System

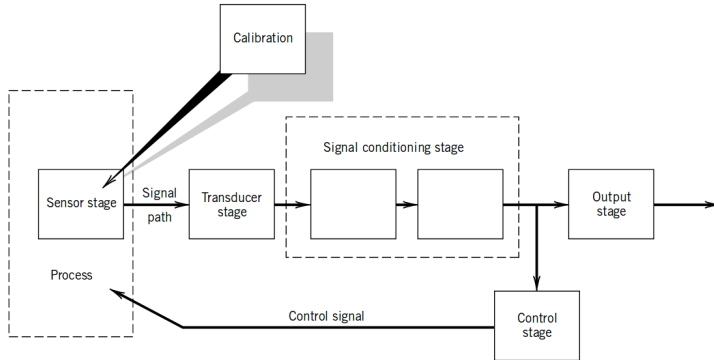
- Definition of a Measurement
- Measurement System Stages
- Brainstorming Activity
- Examples in Mechanical Engineering

# Definition of a Measurement

“A **measurement** is an act of assigning a specific value to a physical variable.”

Text: Theory and Design of Mech. Meas.

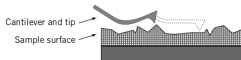
# Measurement System Stages



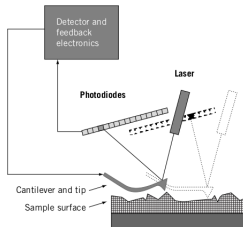
**Figure 1.5** Components of a general measurement system.

## Sensor-Transducer Stage

a **sensor**, a physical element that employs some natural phenomenon... ..to sense the variable being measured



Sensor Stage

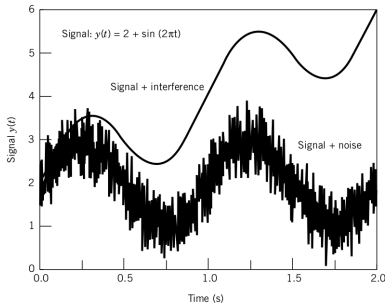


Sensor + Transducer Stage

A **transducer** converts sensed information into a detectable signal

Text, Image: Theory and Design of Mech. Meas.

# Signal Conditioning Stage



- Filtering
- Amplification
- Attenuation
- Excitation
- Linearization
- Electrical Isolation
- Surge Protection

Question: What is the the definition of **signal**?

Image: Theory and Design of Mech. Meas.

## Defintion of a signal

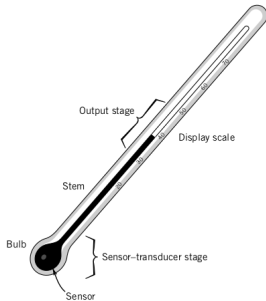
Signal (noun): *a : an object used to transmit or convey information beyond the range of human voice b : the sound or image conveyed in telegraphy, telephony, radio, radar, or television c : a detectable physical quantity or impulse (such as a voltage, current, or magnetic field strength) by which messages or information can be transmitted* - [Merrian Webster](#)

*In signal processing, a signal is a function that conveys information about a phenomenon.[1] Any quantity that can vary over space or time can be used as a signal to share messages between observers.[2] The IEEE Transactions on Signal Processing includes audio, video, speech, image, sonar, and radar as examples of signals.[3] A signal may also be defined as any observable change in a quantity over space or time (a time series), even if it does not carry information.* - [Wikipedia](#)



## Output Stage

The **output stage** indicates or records the value measured. This might be a simple readout display, a marked scale, or even a recording device such as a computer disk drive.



# Brainstorming Activity

Activity: Team Brainstorm  
Duration: ~ 10 minutes  
Groups: 2-3 members



Topic: Remote Probe Concept

- You are designing a remote probe to inspect an environment which can only be accessed from above.
- The goal is to collect as much information as possible from the environment to prepare for a robotic maintenance task.

## Requirements:

- Probe must enter environment through hole ~ 100mm wide
- Probe must exit through same hole leaving nothing behind
- The allowable EMI and RFI is limited. No wifi communication is available

# Examples in Mechanical Engineering

IDETC2022-96785: Development of an Instrumented Rear Suspension to Measure the Tire Forces of a Race Car During Track Driving



# Examples in Mechanical Engineering

IDETC2022-91154: Photometric Stereo Enhanced Light Sectioning  
Measurement for Microtexture Road Profiling



# Examples in Mechanical Engineering

IDETC2022-90082: Automated Weld Path Generation Using  
Random Sample Consensus and Iterative Closest Point Workpiece  
Localization



## Topic 2 - Types of Variables

- Measured Variable
- Independent and Dependent Variables
- Controlled Variables and Parameters
- Extraneous Variables

# Measured Variable

“A \_\_\_\_\_ is an act of assigning a specific value to a physical variable. That physical variable is the **measured variable.**”

Text: Theory and Design of Mech. Meas.

# Independent and Dependent Variables

“If a change in one variable will not affect the value of some other variable, the two are considered independent of each other. A variable that can be changed independently of other variables is known as an \_\_\_\_\_. A variable that is affected by changes in one or more other variables is known as a \_\_\_\_\_. Normally, the variable that we measure depends on the value of the variables that control the process.”

Text: Theory and Design of Mech. Meas.



# Controlled Variables and Parameters

“A variable is \_\_\_\_\_ if it can be held at a constant value or at some prescribed condition during a measurement...  
...complete control of a variable is not usually possible. We use the adjective \_\_\_\_\_ to refer to a variable that can be held as prescribed, at least in a nominal sense...

...we define a \_\_\_\_\_ as a functional grouping of variables. For example, a moment of inertia or a Reynolds number...  
...A \_\_\_\_\_ that has an effect on the behavior of the measured variable is called a control \_\_\_\_\_....”

Text: Theory and Design of Mech. Meas.

# Extraneous Variables

“Variables that are not or cannot be controlled during measurement but that affect the value of the variable measured are called \_\_\_\_\_ . Their influence can confuse the clear relation between cause and effect in a measurement...  
...The effects due to \_\_\_\_\_ can take the form of signals superimposed onto the measured signal with such forms as \_\_\_\_\_ and drift.”

Text: Theory and Design of Mech. Meas.

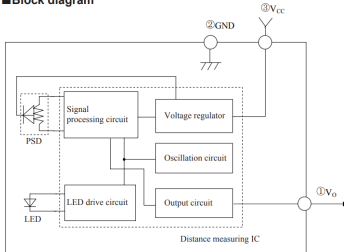
# Class Activity: Measurement System Examples

Individual Activity: Complete the activity and submit your work on ilearn *as an individual*.

## Example 1: SHARP IR Ranger



■ Block diagram



Image, More Info: [Wikipedia-proximity sensor](#)  
Image, More Info: [Wikipedia-PSD](#)

Identify the following measurement stages

- Sensor: \_\_\_\_\_
- Transducer: \_\_\_\_\_
- Signal Conditioning: \_\_\_\_\_
- Output: \_\_\_\_\_

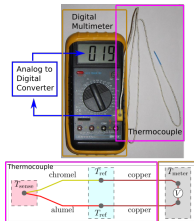
Name at least one for each of the following categories

- Measured Variable: \_\_\_\_\_
- Independent Variable(s): \_\_\_\_\_
- Dependent Variable(s): \_\_\_\_\_
- Controlled Variable(s): \_\_\_\_\_
- Extraneous Variable(s): \_\_\_\_\_

# Class Activity: Measurement System Examples

Individual Activity: Complete the activity and submit your work on ilearn *as an individual*.

## Example 2: Thermocouple with DMM



Identify the following measurement stages

- Sensor: \_\_\_\_\_
- Transducer: \_\_\_\_\_

● Signal Conditioning: \_\_\_\_\_

● Output: \_\_\_\_\_

Name at least one for each category

● Measured Variable: \_\_\_\_\_

● Independent Variable(s):  
\_\_\_\_\_, \_\_\_\_\_

● Dependent Variable(s):  
\_\_\_\_\_, \_\_\_\_\_

● Controlled Variable(s): \_\_\_\_\_

● Extraneous Variable(s): \_\_\_\_\_

Image, More Info: [Wikipedia-Thermocouple](#) Image, More Info: [Omega-Ktype Thermocouple](#)

# Class Activity: Measurement System Examples

Individual Activity: Complete the activity and submit your work on ilearn *as an individual*.

## Example 3: Choose your own example

Write a brief paragraph describing a measurement system of your choice.

Identify the following measurement stages

- Sensor: \_\_\_\_\_
- Transducer: \_\_\_\_\_
- Signal Conditioning: \_\_\_\_\_
- Output: \_\_\_\_\_

Name at least one for each category

- Measured Variable: \_\_\_\_\_

- Independent Variable(s): \_\_\_\_\_

- Dependent Variable(s): \_\_\_\_\_

- Controlled Variable(s): \_\_\_\_\_

- Extraneous Variable(s): \_\_\_\_\_

Image, More Info: [Wikipedia-Thermocouple](#) Image, More Info: [Omega-Ktype Thermocouple](#)

## Topic 3 - Experimental Test Plan

- Parameter Design Plan
- System and Tolerance Design Plan
- Data Reduction Design Plan
- Experimental Design Strategies

# Parameter Design Plan

**Parameter Design Plan:** Determine the test objective and identify the process variables and parameters and a means for their control.

Ask:

- What question am I trying to answer?
- What needs to be measured?
- What variables and parameters will affect my results?

Text: Theory and Design of Mech. Meas.

# System and Tolerance Design Plan

**System and Tolerance Design Plan:** Select a measurement technique, equipment, and test procedure based on some preconceived tolerance limits for error.

Ask:

- In what ways can I do the measurement?
- How good do the results need to be to answer my question?

Text: Theory and Design of Mech. Meas.



# Data Reduction Design Plan

**Data Reduction Design Plan:** Plan how to analyze, present, and use the anticipated data.

Ask:

- How will I interpret the resulting data?
- How will I use the data to answer my question?
- How good is my answer?
- Does my answer make sense?

Text: Theory and Design of Mech. Meas.

# Experimental Design Strategies

- Randomized Tests
- Repetition and Replication.
- Concomitant Methods

# Small Group Activity

**Group Activity:** Find a group of 2-3 students. Complete the activity and submit your work on ilearn as *an individual*. You may submit the same or similar answers as your group members.

## Experimental Test Plan: Fuel/Energy Economy

- 1 Develop an experimental test plan for determining the mileage cost of your vehicle (choose any vehicle) in dollars per mile. Write a short description of the system. (paragraph or bulleted list)

- 2 Identify the following variables for your plan.

- |                            |                           |
|----------------------------|---------------------------|
| ● Measured Variable:       | Variable(s):              |
| ● Independent Variable(s): | ● Controlled Variable(s): |
| ● Dependent                | ● Extraneous Variable(s): |

- 3 Do you expect the results of the study to represent the true mileage of the vehicle? How could you validate (or check) the results?
- 4 What could you do to improve the results of the proposed study?

Image, More Info: [Wikipedia](#)